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# Adsorption of Dyes Reactive Blue 221, N Blue RGB and Acid Blue MTR on Two Different Samples of Activated Carbon

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**Abstract**

Removal of dyes Reactive Blue 221, N Blue RGB and Acid Blue MTR using two different samples of activated carbon by static batch method was studied. Experimental data on optical density of solutions at different concentrations ranging from 10 to 100 mg/L and of solutions after adsorption on activated carbon samples were measured. Calibration curves were plotted and the amount of dye $q_e$ adsorbed was calculated. The data was fitted to Langmuir and Freundlich isotherms for two different carbon samples and different concentration and pH values. Constants were calculated from the slope and intercept values of the isotherms. Coefficient of correlation $R^2$ and Standard Deviation SD were also noted. The data fitted well to the isotherms. Carbon sample $C_1$ showed higher potential to adsorb all the three dyes. Adsorption was higher at lower concentrations. Carbon sample $C_2$ showed better adsorption in acidic pH as compared to in alkaline pH. From the analysis of the data capacity of $C_1$ and $C_2$ to remove the dyes from water have been compared.

***Keywords*** **:** *Adsorption, Reactive Blue 221, N blue RGB, Acid blue MTR, Activated carbon, Isotherms*

## 1. Introduction

Color has always been very important in nature and environment and it continues to play a very significant role in imparting interesting hues to plants, animals and in the lives of mankind. After the dyeing process the residual and unspent substances are usually discharged into the environment. Amongst the different industrial wastewaters with different types of color-causing substances, synthetic textile organic dye wastes occupy a prominent position [1]. The colloidal matter can often be carcinogenic; show allergic reactions; interfere with photosynthesis; clog the pores of the soil; be a breading ground for bacteria and viruses. It is important to remove these pollutants from the waste waters before their final disposal [2-4]. Adsorption of organics from solutions on activated carbon is one of the oldest and widespread applications of this material. Earlier studies of activated carbon adsorption were carried out on fatty acids and later extended to a large number of dyes [5].

Nevine Kamal Amin [6] investigated the use of activated carbons prepared from pomegranate peel for the removal of direct blue dye from aqueous solution. Azza Khaled *et al.* [7]. studied the removal of Direct N Blue-106 from textile dye effluent using activated carbon from agricultural waste material: orange peel. Equilibrium adsorption isotherm for the removal of basic dye (Methylene Blue) from aqueous solution using bituminous coal-based activated carbon has been examined by Emad N *et al.* [8]. The effect of experimental parameters, namely, pH and adsorbent particle size were studied and the maximum adsorptive capacity was determined. B. H. Hameed [9] researched on activated carbon prepared from non-wood forest product waste using it as adsorbent for the removal of methylene blue dye from an aqueous solution.

Abhiti Purai *et al.* [10] tested the ability of cow dung ash, an eco friendly and low cost adsorbent, without any pretreatment to remove color from textile dyes. The adsorption was achieved under different pH and adosrbate concentration.

The present work forms a part of continuing study to compare the adsorptive capacity of different samples of activated carbon and low cost adsorbents.

## 2. Experimental

Samples of Granular Activated Carbon $C_1$ and $C_2$ used were obtained from Brillex Chemical Ltd. Punjab and Industrial Carbon Pvt. Ltd., Gujarat. Surface area of GAC $C_1$ used in the study was 950 $m^2$/g and that of GAC $C_2$ was 600 $m^2$/g. Bulk density of the two was 500~550 and 600~650 g/L respectively. The ash content was 6% in $C_1$ and 5% in $C_2$. From the stock solution of the dyes dilutions were made with distilled water to make different concentrations. Optical density of all the solutions was measured on a spectrophotometer (ELICO make, wavelength range 200~

**Table 1.** Concentration of Dyes ($C_e$) and Amount of Dye Adsorbed Per Gram of the Adsorbent ($q_e$) on $C_1$ & $C_2$ at Different pH

| Dye Name | Reactive Blue 221 pH | | | | N Blue RGB pH | | | | Acid Blue MTR pH | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ 5.49 | $C_2$ 5.49 | $C_2$ 3.43 | $C_2$ 9.27 | $C_1$ 5.20 | $C_2$ 5.20 | $C_2$ 3.74 | $C_2$ 8.01 | $C_1$ 6.51 | $C_2$ 6.51 | $C_2$ 3.80 | $C_2$ 8.69 |
| $C_e$ (mg/L) | $q_e$ | | | | | | | | | | | |
| 10 | 0.32 | 0.25 | 0.26 | 0.20 | 0.40 | 0.22 | 0.27 | 0.21 | 0.35 | 0.24 | 0.26 | 0.19 |
| 20 | 0.51 | 0.41 | 0.49 | 0.31 | 0.59 | 0.38 | 0.45 | 0.32 | 0.51 | 0.37 | 0.47 | 0.34 |
| 30 | 0.67 | 0.60 | 0.60 | 0.45 | 0.73 | 0.55 | 0.71 | 0.44 | 0.68 | 0.59 | 0.63 | 0.51 |
| 40 | 0.89 | 0.79 | 0.80 | 0.58 | 0.90 | 0.71 | 0.93 | 0.57 | 0.87 | 0.79 | 0.86 | 0.72 |
| 50 | 1.07 | 0.99 | 1.03 | 0.73 | 1.02 | 0.87 | 1.12 | 0.70 | 1.05 | 0.99 | 1.07 | 0.96 |
| 60 | 1.22 | 1.08 | 1.14 | 0.92 | 1.15 | 1.01 | 1.31 | 0.88 | 1.21 | 1.20 | 1.33 | 1.17 |
| 70 | 1.33 | 1.13 | 1.23 | 1.02 | 1.28 | 1.15 | 1.51 | 1.03 | 1.39 | 1.40 | 1.56 | 1.37 |
| 80 | 1.42 | 1.19 | 1.27 | 1.06 | 1.42 | 1.24 | 1.70 | 1.19 | 1.59 | 1.58 | 1.80 | 1.55 |
| 90 | 1.45 | 1.22 | 1.30 | 1.07 | 1.49 | 1.31 | 1.84 | 1.31 | 1.73 | 1.75 | 1.97 | 1.67 |
| 100 | 1.49 | 1.24 | 1.35 | 1.10 | 1.53 | 1.39 | 1.85 | 1.33 | 1.85 | 1.77 | 2.01 | 1.70 |

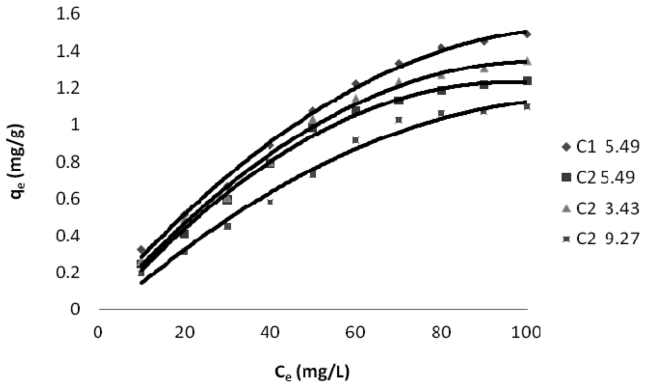


**Fig. 1.** Adsorption Isotherm for dye Reactive Blue 221 on $C_1$ & $C_2$ at different pH values.

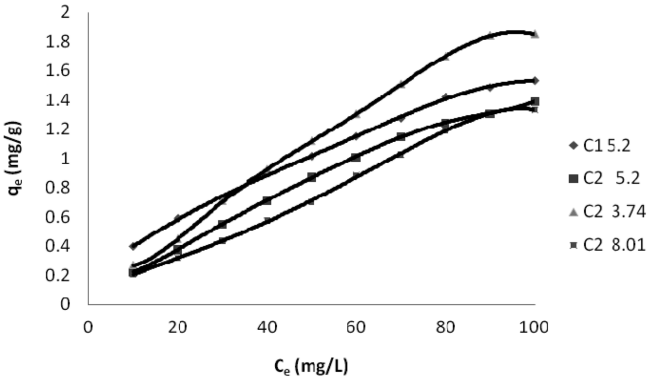


**Fig. 2.** Adsorption Isotherm for dye N Blue RGB on $C_1$ & $C_2$ at different pH values.

900 nm). One gram of activated carbon was placed in each 50 mL solution of 10 to 100 ppm. The solutions were shaken and kept in a thermostat for 24 h. The samples were then filtered and analyzed spectrophotometrically.

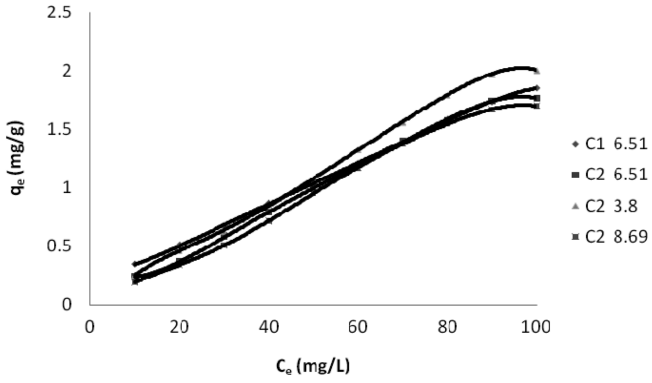


**Fig. 3.** Adsorption Isotherm for dye Acid Blue MTR on $C_1$ & $C_2$ at different pH values.

## 3. Results and Discussion

### *3.1. Effect of initial dye concentration*

Table 1 and Figs. 1~3 show the amount qe of Reactive Dye Blue 221, N Blue RGB and Acid Blue MTR adsorbed by $C_1$ and $C_2$ samples of granulated activated carbon at various pH values and various ppm concentrations. It can be seen that $q_e$ on GAC $C_1$ and $C_2$ was higher at lower ppm concentration as compared to the adsorption at higher ppm concentration with the adsorbent dose being kept constant for all the three dyes . At 10 ppm concentration and initial (slightly acidic) pH of 5.49 $C_1$ adsorbed 0.645 mg/g of the dye Reactive Blue 221 and $C_2$ adsorbed 0.495 mg/g. At 100 ppm concentration the adsorption of Reactive Blue 221 was 2.978 mg/g, 2.470 mg/g, on $C_1$ and $C_2$ respectively at the same pH. This pattern of higher adsorption on lower ppm concentrations was observed for all the three reactive dyes. $C_1$ showed better adsorption as compared to adsorption on $C_2$.

**Table 2**. Values of Different Constants for Polynomial Fit Data

| Dye Name | Reactive Blue 221 pH | | | | N Blue RGB pH | | | | Acid Blue MTR pH | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ 5.49 | $C_2$ 5.49 | $C_2$ 3.43 | $C_2$ 9.27 | $C_1$ 5.20 | $C_2$ 5.20 | $C_2$ 3.74 | $C_2$ 8.01 | $C_1$ 6.51 | $C_2$ 6.51 | $C_2$ 3.80 | $C_2$ 8.69 |
| A | 2.639 | -0.048 | 1.04767 | 2.26633 | 5.06333 | 1.03967 | 1.98067 | 3.59933 | 4.10967 | 2.85933 | 3.91067 | 2.604 |
| $B_1$ | 0.35455 | 0.46783 | 0.4137 | 0.11642 | 0.31495 | 0.32011 | 0.3098 | 0.02532 | 0.26567 | 0.13414 | 0.09604 | 0.05349 |
| $B_2$ | 0.00145 | -0.00143 | -4.82E-05 | 0.00472 | 4.02E-04 | 7.80E-04 | 0.0036 | 0.00563 | 0.00209 | 0.00633 | 0.00784 | 0.00835 |
| $B_3$ | -2.31E-05 | -8.04E-06 | -1.55E-05 | -3.96E-05 | -9.74E-06 | -1.32E-05 | -3.15E-05 | -3.55E-05 | -1.44E-05 | -4.39E-05 | -5.13E-05 | -5.73E-05 |
| $r^2$ | 0.9985 | 0.99499 | 0.99359 | 0.99614 | 0.99835 | 0.99961 | 0.99836 | 0.99829 | 0.99954 | 0.99896 | 0.99847 | 0.99985 |
| SD | 0.39819 | 0.62087 | 0.7568 | 0.51775 | 0.38997 | 0.1959 | 0.56562 | 0.41698 | 0.27311 | 0.4416 | 0.60985 | 0.16964 |

### *3.2. Effect of pH*

Adsorption of the three dyes has been studied at different pH for carbon sample $C_2$ and at one pH for $C_1$. $C_2$ was greatly effected by change in pH of the aqueous solution as can be seen in Tables 1 and Figs. 1~3. Amount of dye adsorbed $q_e$ on $C_2$ in acidic pH is higher at all ppm concentrations as compared to adsorption in a lesser acidic and an alkaline environment. At an acidic pH of 3.43 at 10 ppm concentration $C_2$ adsorbed 5.21 mg/g of the dye Reactive Blue 221. In an alkaline pH of 9.27 the same $C_2$ adsorbed only 3.90 mg/g leaving behind a good number of free adsorption sites on the adsorbent. The same pattern could be observed on N Blue RGB and Acid Blue MTR. At 10 ppm concentration $C_2$ adsorbed 5.40 mg/g and 5.10 mg/g of N Blue RGB and Acid Blue MTR at acidic pH. At alkaline pH the adsorption was only 4.10 mg/g and 3.80 mg/g respectively at the same 10 ppm concentration of N Blue RGB and Acid Blue MTR.

$C_1$ as compared to $C_2$ shows higher adsorption at initial pH .It also shows better adsorption than $C_2$ did in acidic environment.

### *3.3. Data fit for Simple isotherms*

It can be seen from Figs. 1~3 that the experimental data fitted well to polynomial equation of the type:

$$q_e = A + B_1C_e + B_2C_e^2 + B_3C_e^3$$

The constants and standard deviation are given in Table 2. Comparative adsorption of all the dyes on $C_1$ & $C_2$ at various pH values is shown in Figs. 1~3. Maximum dye removal of N Blue RGB was observed on $C_1$ at acidic pH 5.2. Least adsorption efficiency of all the three dyes was shown by $C_2$ at alkaline pH values. On the whole $C_1$ exhibited most favourable adsorption at initial pH values as compare to $C_2$. $C_2$ showed maximum adsorption at acidic pH.

### *3.4. Langmuir isotherm at various pH*

The experimental data was fitted to linear form of Langmuir isotherm for all the pH values of the three dyes and for the two samples of GAC.

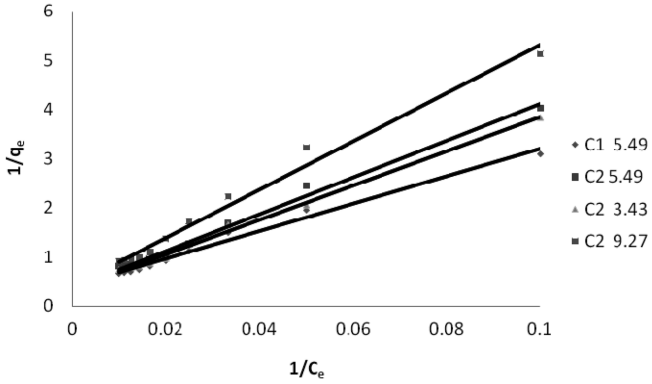


**Fig. 4.** Langmuir Isotherm for dye Reactive Blue 221 on $C_1$ & $C_2$ at different pH values.

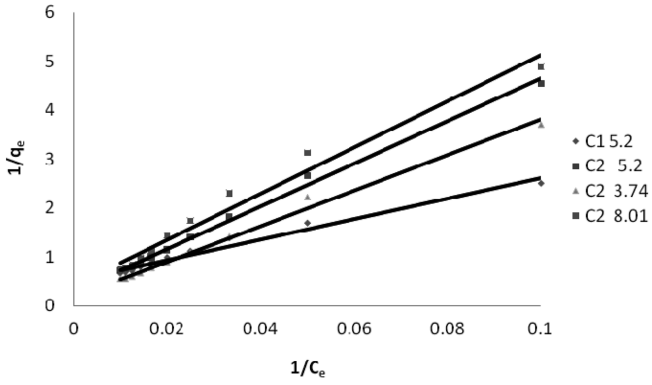


**Fig. 5.** Langmuir Isotherm for dye N Blue RGB on $C_1$ & $C_2$ at different pH values.

Q and b the Langmuir constants were calculated from the straight line slope and intercept of linear plot between $1/q_e$ and $1/C_e$ as shown in Fig. 4 to 6.

Table 3 gives the values of Langmuir constants Q and b along with the values of $r^2$ and SD for all the three dyes and their varied pH values and for the two samples of GAC, $C_1$ and $C_2$. Value of constants Q b signify good adsorption of all

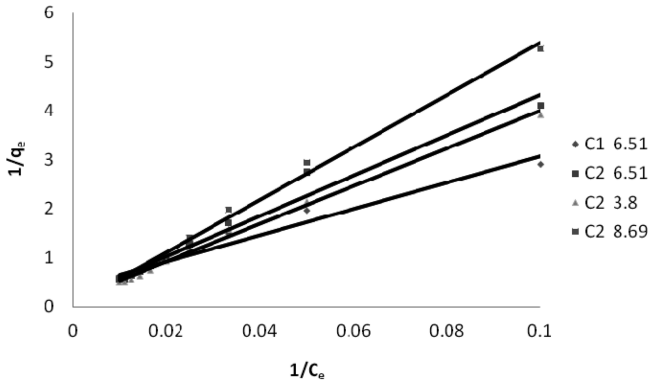


**Fig. 6.** Langmuir Isotherm for dye Acid Blue MTR on $C_1$ & $C_2$ at different pH values.

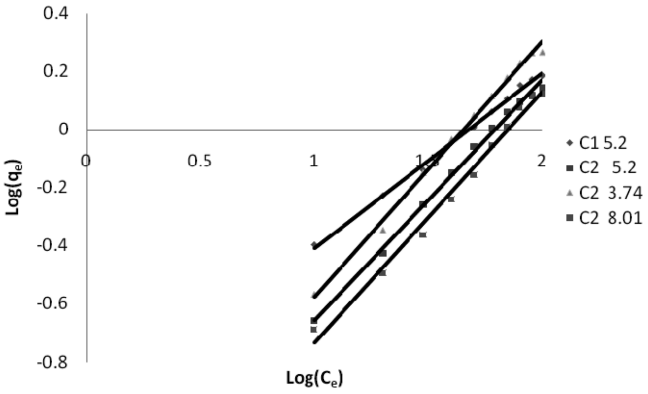


**Fig. 8.** Freundlich Isotherm for dye N Blue RGB on $C_1$ & $C_2$ at different pH values.

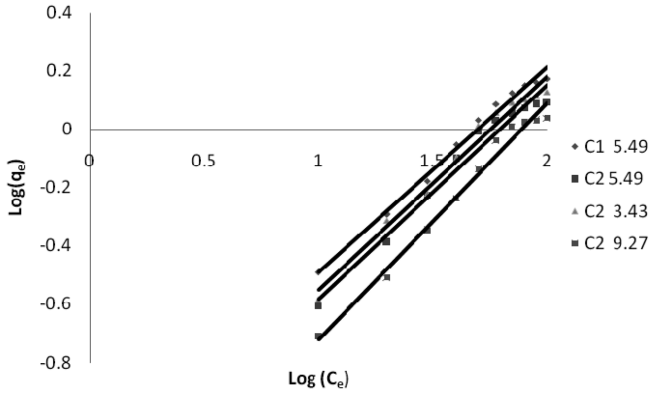


**Fig. 7.** Freundlich Isotherm for dye Reactive Blue 221 on $C_1$ & $C_2$ at different pH values.

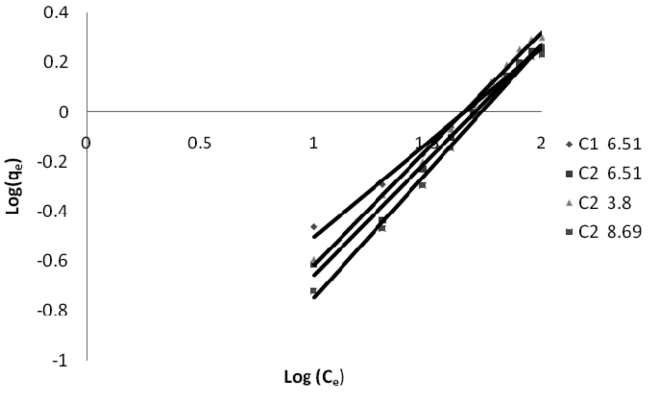


**Fig. 9.** Freundlich Isotherm for dye Acid Blue MTR on $C_1$ & $C_2$ at different pH values.

**Table 3.** Values of Different Constants for Langmuir Isotherm at Various pH Values

| Dye Name | Reactive Blue 221 pH | | | | N Blue RGB pH | | | | Acid Blue MTR pH | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ 5.49 | $C_2$ 5.49 | $C_2$ 3.43 | $C_2$ 9.27 | $C_1$ 5.20 | $C_2$ 5.20 | $C_2$ 3.74 | $C_2$ 8.01 | $C_1$ 6.51 | $C_2$ 6.51 | $C_2$ 3.80 | $C_2$ 8.69 |
| Q | 46.361 | 52.219 | 51.520 | 41.859 | 38.402 | 59.277 | 109.29 | 42.123 | 44.17 | 72.993 | 114.15 | 230.95 |
| b | 0.015 | 0.011 | 0.012 | 0.010 | 0.024 | 0.008 | 0.005 | 0.010 | 0.018 | 0.007 | 0.005 | 0.002 |
| $r^2$ | 0.964 | 0.983 | 0.978 | 0.976 | 0.961 | 0.989 | 0.983 | 0.969 | 0.954 | 0.945 | 0.986 | 0.977 |
| SD | 0.008 | 0.007 | 0.008 | 0.011 | 0.006 | 0.007 | 0.007 | 0.012 | 0.008 | 0.014 | 0.007 | 0.012 |

**Table 4.** Values of Different Constants for Freundlich Isotherm at Various pH Values

| Dye Name | Reactive Blue 221 pH | | | | N Blue RGB pH | | | | Acid Blue MTR pH | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_1$ 5.49 | $C_2$ 5.49 | $C_2$ 3.43 | $C_2$ 9.27 | $C_1$ 5.20 | $C_2$ 5.20 | $C_2$ 3.74 | $C_2$ 8.01 | $C_1$ 6.51 | $C_2$ 6.51 | $C_2$ 3.80 | $C_2$ 8.69 |
| $K_F$ | 1.288 | 0.955 | 1.049 | 0.576 | 1.920 | 0.655 | 0.683 | 0.495 | 1.108 | 0.516 | 0.565 | 0.344 |
| N | 1.425 | 1.357 | 1.369 | 1.225 | 1.648 | 1.208 | 1.128 | 1.149 | 1.322 | 1.075 | 1.069 | 0.984 |
| $r^2$ | 0.987 | 0.974 | 0.981 | 0.985 | 0.997 | 0.997 | 0.995 | 0.989 | 0.992 | 0.990 | 0.994 | 0.993 |
| SD | 0.027 | 0.040 | 0.034 | 0.034 | 0.011 | 0.016 | 0.021 | 0.030 | 0.023 | 0.032 | 0.236 | 0.029 |

the three dyes on $C_1$ as compared to $C_2$ at initial pH. It also indicates a better adsorption at acidic pH on $C_2$.

### *3.5. Freundlich isotherm at various pH*

The linear plots of log $q_e$ and log $C_e$ for Freundlich isotherm are shown in Figs. 7~9. Table 4 shows the Freundlich constants $K_F$ and n calculated from the slope and intercept of log $q_e$ and log $C_e$ along with $R^2$ and SD. $K_F$ (parameter relative to adsorption capacity) and n (process intensity) were calculated. Values of constant $K_F$ indicate higher adsorption capacity on Carbon sample $C_1$ as compared to $C_2$.

## 4. Conclusions

Granulated Activated Carbon sample $C_1$ and $C_2$ can be effectively used for the removal of dyes from wastewater by adsorption. The present study shows that there is a decrease in percentage removal of dye of carbon per gram with increase in ppm concentration of the dye. Change in pH values showed higher adsorption at acidic pH. The three dyes obeyed Langmuir and Freundlich isotherms. Langmuir isotherm gave a better fit. Carbon sample $C_1$ showed high adsorption for all the three dyes.

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